Evaluating a Remote Tele-mentoring Gameplay Setup for Teaching Laparoscopic Suturing Skills

Dehlela Shabir
Department of Surgery
Hamad Medical Corporation
Doha, Qatar

Shidin Balakrishnan
Department of Surgery
Hamad Medical Corporation
Doha, Qatar

Jhasketan Padhan
Department of Surgery
Hamad Medical Corporation
Doha, Qatar

Elias Yaacoub
Department of Computer Science
Qatar University
Doha, Qatar

Amr Mohammed
Department of Computer Science
Qatar University
Doha, Qatar

Zhigang Deng
Department of Computer Science
University of Houston
Houston, Texas, USA

Abdulla Al-Ansari
Department of Surgery
Hamad Medical Corporation
Doha, Qatar

Panagiotis Tsiamyrtzis
Department of Mechanical Engineering
Politecnico di Milano
Milan, Italy

Nikhil V. Navkar
Department of Surgery
Hamad Medical Corporation
Doha, Qatar

***Abstract*—The work presents an evaluation study to investigate the potency of remote tele-mentoring gameplay for training in minimally invasive surgeries, as compared to training through traditional in-person methods for teaching suturing skills. A remote tele-mentoring prototype is implemented to simulate the gameplay. Augmented surgical instruments (remotely controlled by a mentor) are overlaid onto the surgical video to assist the mentee with visual cues. The study evaluates teaching of the simulated surgical task of laparoscopic intracorporeal suturing among mentor-mentee pairs simulating a multiplayer game. It comprises a teaching stage followed by a testing stage, where error counts and duration during the gameplay are recorded and compared. The teaching stage was conducted in either of two modes, Mode-I (traditional in-person mentoring mode) or Mode-II (remote tele-mentoring gameplay mode). Results show that Mode-II took a higher duration in the teaching stage, but both modes performed equivalently in the testing stage. Thus, the efficacy of training through remote tele-mentoring in a gameplay mode is comparable to that of traditional in-person mentoring.**

***Keywords*—Gameplay, Tele-mentoring, Laparoscopy, Surgical skills, Surgical training**

I. Introduction

Minimally invasive surgery (MIS) is a revolutionary surgical technique which involves insertion of customized surgical instruments and a rod lens video camera through skin incisions or orifices on the body. The surgical video allows the surgeon to explore the internal cavity and operate on organs from outside the body [1]. In contrast to open surgeries, MIS procedures avoid the morbidity of conventional surgical wounds through reduced postoperative pain, minimized scarring, earlier hospital discharge, and easier recuperation. Due to its prevalence, the demand for education and training in MIS has surged significantly. However, it poses a steep learning curve and relies heavily on skills such as hand-eye coordination, manipulating tools with a limited range of motion and field of view, visual tactility, and haptic sensorimotor skills [2]. Traditional training approaches on animals or cadavers have become obsolete and physical apprenticeship model of training in the operating room or skill centers appear insufficient [3]. Furthermore, the COVID-19 pandemic has severely impeded exposure among residents due to closing of training centers, curtailment of educational activities and limited availability of experienced surgeons [4]. This has resulted in the proliferation of technologies like virtual reality (VR) simulations [5]–[7], augmented reality (AR) [8], [9], serious games [10]–[12], and tele-mentoring [13]–[15] as feasible alternatives to traditional in-person training.

Existing innovations in MIS training include procedure specific simulators, such as for tumor resection simulator [16], eye surgery, [17] and VR-based [5]–[7]. The concept of medical education through serious games [18] can be found in several works [10]–[12]. Such an approach to training, (where the trainee learns through interactivity and engagement in play), has also seen numerous applications in MIS [19]–[21]. In particular, AR-based training through tele-mentoring includes the use of screen annotations [22], [23], hand gestures [24], [25], and augmented tooltip movements (in both robotic MIS [14], [26], [27] and laparoscopic MIS [13]–[15]). Such immersive tele-mentoring technologies could alleviate the concern regarding acquisition of proficient surgical skills and can be simulated as a serious gameplay.

The aim of this paper is to advance on the work of the aforementioned research and investigate the efficacy of a remote tele-mentoring prototype in a mulitplayer gameplay setting [14], [28]. A surgical task of laparoscopic intracorporeal suturing is selected for the training. The study is conducted in

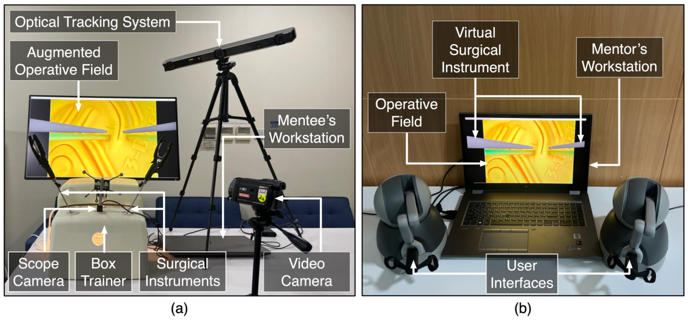

Fig. 1. Setup of the remote tele-mentoring prototype at (a) mentee side and (b) mentor side.

mentor-mentee pairs. The prototype can be considered as a two player game where one player imparts skills to another player in a simulation training. It allows the mentee to make their own decisions and begin to understand the surgical sub-steps at each point as the game progresses. In this dual game, the mentor acts as supervising player instructing the moves. The paper compares traditionally in-person hands-on mentoring with training through remote tele-mentoring gameplay and shows improvement in content retention and comprehension.

II. Materials and Methods

A. Remote Tele-Mentoring Prototype

A remote tele-mentoring prototype was developed that connects a mentor (situated remotely) with a mentee (in the operating/training room). The word 'remote' signifies that the mentor and the mentee can be at two locations geographically apart. The implementation details are presented in the work by Shabir et al. [14], [28]. The prototype (shown in Fig. 1) transfer audio-visual cues between mentee workstation and mentor workstation over the Internet. The real-time view of the operative field acquired by the scope at the mentee workstation is shared with the mentor's workstation. Virtual surgical instruments are displayed on the screen of the mentor's workstation. The mentor utilizes user interfaces to control motion of the virtual instruments [29]. The motion of the virtual surgical instruments performed by the mentor is transferred back to the mentee's workstation, augmented onto the operative field, and displayed on the screen. Thus, the mentor can remotely demonstrate to the mentee the required motion of the surgical instruments along with audio cues. This enables real-time interaction between the mentor and the mentee, and facilitates transfer of surgical knowledge.

B. Simulated Surgical Task

To simulate mentoring sessions, we chose a laparoscopic intracorporeal suturing procedure as the surgical task. This task specifically focuses on tying a knot within a cavity using laparoscopic instruments. For the simulation, we utilized a suture pad (3D-Med Inc., USA), while the laparoscopic instruments chosen for the task were needle drivers (Richard Wolf Inc., Germany). As the suture size was short (15 cm), a hold-needle technique was used. The task was divided into steps, as shown in Fig. 2 and Table I. These steps are taken from our previous work [30]. For each step, an error was assigned. Before the start of the task, the needle was preloaded at around ninety degrees to the driver instrument held in the dominant hand. The time for the study starts once the needle penetrates the soft tissue suture pad and ends when a square knot is formed.

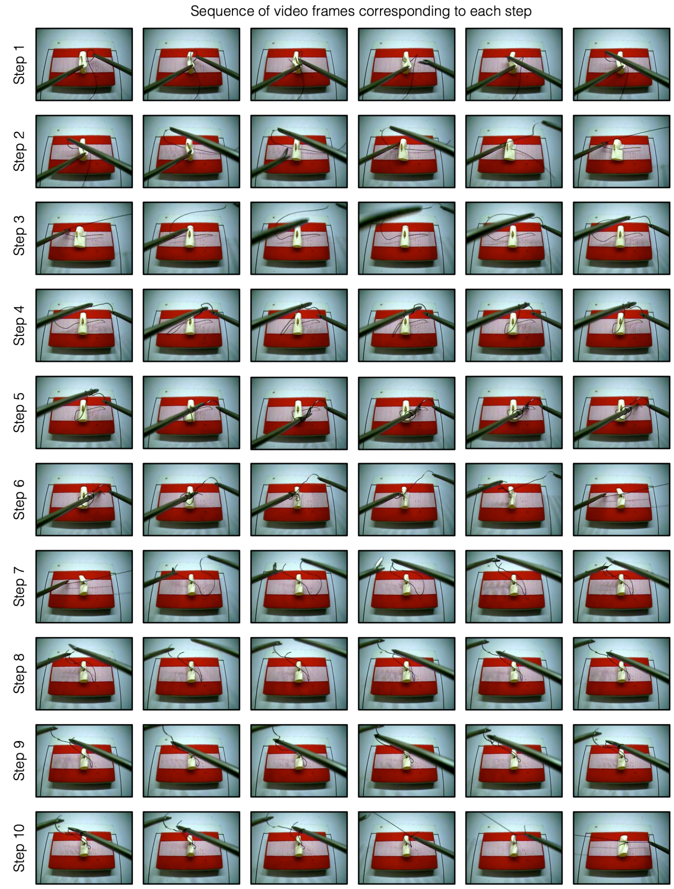

Fig. 2. Images capturing the sequential steps of the laparoscopic intracorporeal suturing task. The images are taken from St. John Surgical Residency FLS Expanded Video Tutorial Series: Task 5 - Intracorporeal Suture (uploaded at https://www.youtube.com/watch?v=hAzhqYid5jc).

C. Experimental Setup

Two mentoring modes were used during the study. In Mode-I, traditional methods of mentoring were used. This involved the mentor demonstrating to the mentee the sub-steps of the surgical task by (a) asking the mentee to step aside and to take control of the surgical instruments to show the required motion, and/or (b) explaining the required motion of the surgical instruments via hand gestures or physically pointing to the visualization screen with the rendered operating field. In Mode-II, the developed remote tele-mentoring prototype (Fig. 1) was used to simulate the gameplay. Virtual models of surgical instruments were augmented onto the operating field and rendered on the visualization screen. The motion of the augmented surgical instruments was controlled by the mentor

TABLE I
GAMEPLAY STEPS TO COMPLETE LAPAROSCOPIC INTRACORPOREAL SUTURING TASK

Steps		Tool Interaction in Each Step	Counted Errors
Throw a stitch	Step 1	Hold the soft tissue suture pad using non-dominant hand and place the needle through the cavity using dominant hand	- Incomplete bite of the soft tissue suture pad - Trajectory does not follow needle curvature - Soft tissue suture pad is torn - Non-dominant hand holds the tissue aggressively - Needle doesn't remain in camera frame
	Step 2	Once the needle is placed through the cavity, use the non-dominant hand to protect the soft tissue suture pad while pulling the suture thread using dominant hand	- Needle is initially not pulled laterally - The needle is pulled away from the soft tissue suture pad without support from the tool - Thread tail is not left too short or too long - Needle does not remain in camera frame - Needle is pulled aggressively
Put the first throw of square knot	Step 3	Orient the needle in crescent shape such that suture thread and non-dominant hand tool are parallel	- Did not rotate the needle to downward crescent shape - The suture thread is not parallel to hub - The tool is not placed on top of the suture thread
	Step 4	Use the needle (held in dominant hand) to wrap twice around the non-dominant hand	- Did not rotate the needle to downward crescent shape - The suture thread is not parallel to hub - The tool is not placed on top of the suture thread
	Step 5	Grab the free end of the suture thread using non-dominant hand	- End of thread is not held
	Step 6	Pull the hand opposite to each other to put the first throw of the square knot on the soft tissue suture pad	- Non-dominant hand is not pulled first - Pulling is done upwards instead of sideways
Put the second throw of square knot	Step 7	Switch the needle from dominant to non-dominant hand such that suture thread and dominant hand tool are parallel	- Needle is not switched between hands - Did not rotate the needle to downward crescent shape - The suture thread is not parallel to hub - The tool is not placed on top of the suture thread
	Step 8	Use the needle (held in non-dominant hand) to wrap once around the dominant hand	- Wrapping and tying is done away from the soft tissue suture pad
	Step 9	Grab the free end of the suture thread using the dominant hand	- End of thread is not held
	Step 10	Pull the hand opposite to each other to put the second throw of the square knot on the soft tissue suture pad	- Non-dominant hand is not pulled first - Pulling is done upwards instead of sideways

* The gameplay steps, the interaction of tool in each steps, and the counted errors are taken from Shabir et al. [30]

using user interfaces (Touch Haptic Device by 3D Systems, USA with Twee Stylus by BBZ, Italy) with clutch. The clutch enabled economical repositioning of the stylus.

The study involved (a) twelve mentees with no prior knowledge of laparoscopic skills, (b) two mentors (namely Mentor-1 and Mentor-2) with expertise in mentoring the surgical task of suturing as per the sub-steps, and (c) an external observer. The participants for this study were chosen from the surgical department at Hamad General Hospital in Qatar. The study received approval from the institutional review board. A research information sheet was presented to obtain the informed consent. The mentees were divided into two groups of six members and each group was assigned to a mentor. Each mentor was asked to mentor the group with three mentees under Mode-I and the remaining three under Mode-II. The role of the external observer was to observe the mentoring session for each mentor-mentee pair. The observer understands the mentoring for both modes as well as the advice that needs to be given by the mentor to the mentee.

Before the study, the mentors were first familiarized with the 3D Touch interface of the tele-mentoring prototype to demonstrate augmented surgical instrument motion in Mode-II. The mentors were also provided with a reference script to assist them in their mentoring sessions. The script details the mentoring advice to successfully execute each sub-step of the surgical task (as shown in Fig. 2 and Table I). The same reference script was used for both the modes. The mentees were first introduced to laparoscopic setup in the study and were briefed on how mentoring will take place in Mode-I and Mode-II, respectively. To develop the necessary hand-eye coordination for laparoscopic skills, each mentee performed a pre-experiment peg transfer task. This task was adopted from the Fundamentals of Laparoscopic Surgery [31], [32] and served as a foundational exercise for the mentees. To record the parameters during the study, an off-the-shelf video camera was used. It was pointed towards the visualization screen (to record the operating field) and the box trainer (to record hand and laparoscopic tool movements). The camera also recorded audio to analyze mentor-mentee communication. The study was conducted in the two stages as described hereafter.

At the first stage, each mentee performs all the sub-steps of the surgical task under constant guidance from the mentor. The observer examines the task that was being performed by the mentor-mentee pair. After the mentoring session between the mentor and the mentee pair, a questionnaire is given to the mentor, the mentee, and the observer (Table II). At the second

TABLE II
POST-MENTORING QUESTIONNAIRE

Score given by	Questionnaire on the Likert scale of 1 to 5*	Average Score	
		Mode-I	***Mode-II***
Mentor	I (mentor) was able to give mentoring instruction easily	4.17 ± 0.41	3.83 ± 0.41
	The mentee was able to understand mentored instructions well	4.17 ± 0.75	4.17 ± 0.41
	The mentee was able to apply mentored instructions well	4.00 ± 1.10	3.67 ± 1.03
	Information was efficiently exchanged during mentoring session	4.33 ± 0.82	4.33 ± 0.52
Mentee	Mentor's instructions were helpful	4.83 ± 0.41	4.50 ± 0.55
	Mentor's instructions were easy to follow	4.67 ± 0.82	4.50 ± 0.55
	I (mentee) was able to apply mentored instructions well	4.00 ± 0.63	4.00 ± 1.10
	Information was efficiently exchanged during mentoring session	4.33 ± 0.82	4.50 ± 0.55
External Observer	Mentor intervened and provided mentoring when needed	4.83 ± 0.41	4.50 ± 0.55
	Mentor's intervention was successful	4.67 ± 0.82	4.50 ± 0.55
	Mentor's intervention was frequent	4.00 ± 0.63	4.00 ± 1.10
	Mentor's use of verbal and visual cues was balanced	4.33 ± 0.82	4.50 ± 0.55

* 1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4-Agree, and 5-Strongly agree

stage, the mentee performs the surgical task without mentor's guidance. The mentor only intervenes when the mentee is stuck in the task and cannot proceed further. The mentor observes the mentee's performance during the test. After the test, the mentor is asked to rate the performance of the mentee using a questionnaire (Table III). Apart from the questionnaire, the following parameters are recorded using a video camera at both the stages: (a) duration it takes to complete each step, (b) the total duration to complete all the steps, (c) a success percentage for each step, and (d) the total success percentage to complete all the steps. The success percentage for a step is calculated as hundred minus the error percentage. The error percentage is the percentage of errors made by mentee in a step over the total number of errors assigned for that step. The errors made for each step are described in Table I. t-Tests were used to calculate the statistical differences between the means of aforementioned recorded parameters.

III. RESULTS

Table II and Table III summarize the outcomes of the questionnaires. No significant difference was found between Mode-I and Mode-II. The results corresponding to the recorded durations and success percentage are explained in the following subsections.

TABLE III
POST-TEST QUESTIONNAIRE

Score given by	Questionnaire on the Likert scale of 1 to 5*	Average Score	
		Mode-I	***Mode-II***
Mentor	The mentee was able to apply learnings from the mentoring session and thus it assisted in the test performance	4.00 ± 0.63	3.50 ± 1.05
	The mentee faced new struggles in the test (which did not come up during mentoring)	3.00 ± 0.89	3.00 ± 1.26

* 1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4-Agree, and 5-Strongly agree

A. Surgical task durations

1) Mode I versus mode II: For the first stage (stage-I), the average teaching time for mode-I (66.29 seconds) and mode-II (70.75 seconds) are similar ($p = 0.38$). As shown in Fig. 3a, half of the recorded surgical task durations (in the lower half of the whisker plot) for mode-I are concentrated between 7 seconds and 38.5 seconds and for mode-II between 5 seconds and 42.5 seconds. They do not differ significantly ($p = 0.08$). The other half of the whisker plot in the case of mode-I is concentrated over a shorter spread of 38.5 seconds to 145 seconds, whereas in the case of mode-II, it varies from 42.5 seconds to 209 seconds. This variation shows in nearly half of the training scenarios, mode-II may take more time to teach than mode-I. For the second stage (stage-II, shown in Fig. 3b), there is no significant difference between the durations of mode-I and mode-II ($p = 0.22$). This means that although mode-II took more time for teaching, the mentee's test performance was on par with mode-I during the testing stage.

2) Stage I versus stage II: It was observed that during stage-II (i.e. the testing stage), the mentees took less time to complete the surgical task for both mode-I ($p = 0.07$) and mode-II ($p = 0.001$), as compared to stage-I (i.e. the teaching stage). As shown in Fig. 3c and Fig. 3d, the average surgical task duration for mode-I reduces from 66.29 seconds to 44.69 seconds; and for mode-II, it reduces from 70.75 seconds to 36.19 seconds. In addition, the three-fourth quarter of mode-I data fall under 47.75 seconds, while for mode-II, data falls under 46.25 seconds. This shows that for both the modes, the teaching stage took more time than the testing stage.

B. Surgical steps durations

1) Mode I versus mode II: Fig. 3e and Fig. 3f show the comparison of the durations required for each surgical step in mode-I versus mode-II. The durations for step 3 and step 7 were excluded from the experiment. It was observed that as the mentee dropped the needle during these steps, it was hard to pick the needle back and orient it correctly. It would require a set of skills to be taught separately and thus were excluded from the experiment.

In stage I (Fig. 3e), mode-II took more time than mode-I for surgical step 1 (mode-II average duration of 167 seconds

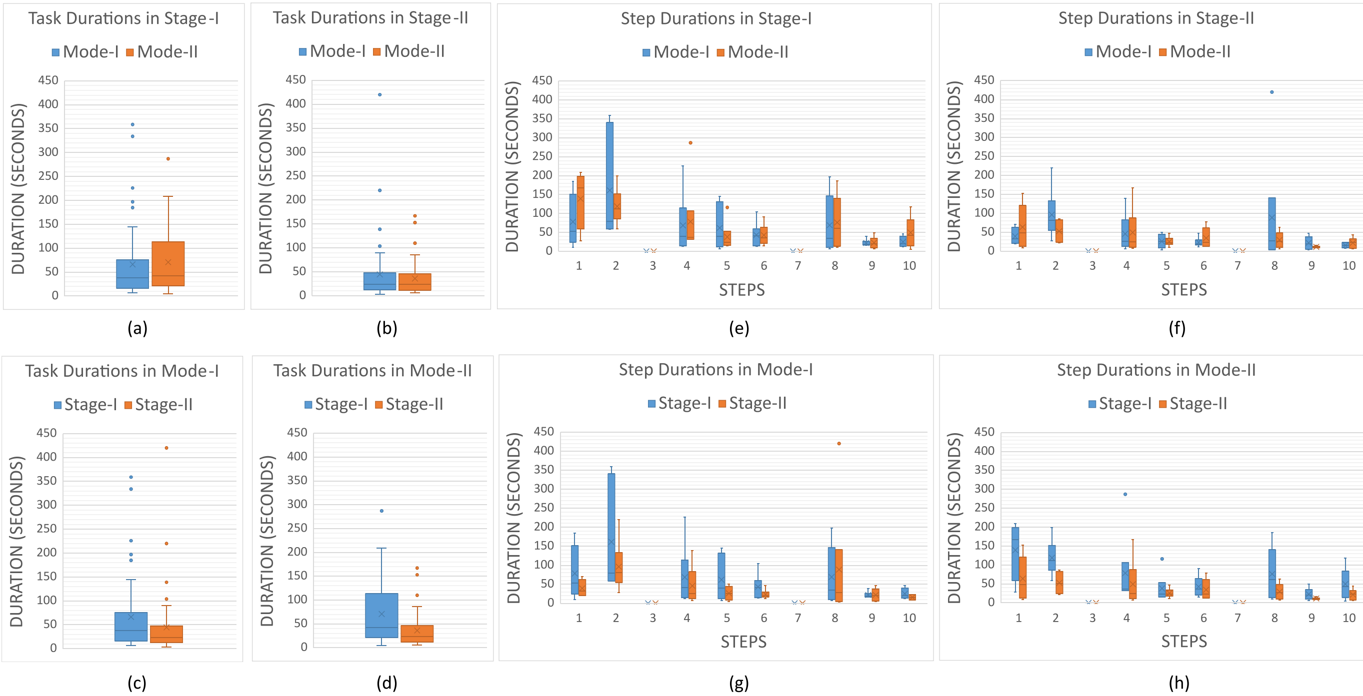

Fig. 3. (a) Surgical task durations in stage-I, (b) Surgical task durations in stage-II, (c) Surgical task durations in mode-I, (d) Surgical task durations in mode-II, (e) Surgical steps durations in stage-I, (f) Surgical steps durations in stage-II, (g) Surgical steps durations in mode-I, (h) Surgical steps durations in mode-II.

vs. mode-I average duration of 53 seconds) and surgical step 8 (mode-II average duration of 61 seconds vs. mode-I average duration of 35 seconds). Whereas for surgical step 2, mode-I (161.5 seconds) took more time than mode-II (118.33 seconds). The duration variations for different steps can be summarized as follows:

- In the case of step 1, the scoop motion required to insert the needle through the slit on the tissue suture pad could be easily demonstrated by hand gestures that involve wrist movements. As compared to the augmented surgical instrument motion in mode-II, it was easier in mode-I for the mentor to demonstrate the wrist movement to the mentee and for the mentee to understand and replicate it using the handles of the laparoscopic tools. The required wrist movement cannot be demonstrated in mode-II.
- Step 8 required the mentee to use the needle (held in the non-dominant hand) to wrap once around the dominant hand. It was observed that in Mode-II both the augmented tools were overlapped with each other during the step 8, and it became difficult for the mentee to distinguish left from the right tool. This confusion caused the mentor to repeat the instructions using verbal cues.
- For step 2 (involving the pulling of the needle from the tissue using the non-dominant hand as support), the mentees found it was difficult in mode-I to translate verbal instructions into actions. This required the mentor to take control and give them a visual demonstration of the step, which resulted in the increase of time. In mode-II, the mentor utilized augmented surgical instruments to demonstrate the proper placement of the non-dominant tool beneath the thread and the necessary motion to pull the needle away from the tissue.

In stage II (Fig. 3f), mode-I (81 seconds) took more time than mode-II (51 seconds) for step 2. The main reason is:

- For step 2 in mode-I, most of the mentees forgot the details of the step and needed the mentor to intervene. On the other hand, for mode-II, the majority of the mentees followed the sub-steps as demonstrated during stage-I. They were able to better understand the breakdown of the step during training and apply them during their tests. Visual cues (comprising of augmented tool motion) along with the audio cues assist the mentees to learn and recall the details of the step, compared to verbal instructions only.

2) Stage I versus stage II: In the case of mode-I, each step took either the same or less time for stage-II than stage-I. The durations were reduced for steps 1, 2 and 6 (Fig. 3g). The mentees were able to grasp the instructions by the mentors in stage-I and replicated them in stage-II without the mentor's assistance. The absence of the mentor's intervention reduced the time for stage-II. In the case of mode-II, similar behaviors were observed (Fig. 3h). The used time was reduced for step 1 (167 seconds to 48.5 seconds), step 2 (112 seconds to 51 seconds) and step 8 (61 seconds to 29.67 seconds). This shows that although these steps were difficult to be taught using mode-II, they were comprehended well enough to reduce the completion time during the testing stage-II.

C. Success percentages for surgical tasks

1) Mode I versus mode II: No statistically significant difference was found between Mode I and Mode II. In stage-I (Fig. 4a), mode-I had an average success percentage of 87.69% and mode-II had 91.36% ($p = 0.3$), whereas in stage-II (Fig. 4b), mode-I had an average success rate of 83.86% and mode-II had 87.97% ($p = 0.47$). On average, both the teaching and testing stages were equally successful.

2) Stage I versus stage II: For both mode-I and mode-II, the success percentages decrease as the mentees move from stage-I to stage-II (Fig. 4c and Fig. 4d). It can be observed that the decrease is similar for mode-I (decreases by 3.83%) and mode-II (decreases by 3.39%). This infers that both the modes were equivalent in teaching mentees the steps, as well as for the mentees to apply what they have learnt.

D. Success percentages for surgical steps

1) Mode I versus mode II: In stage I (Fig. 4e), steps 6 and step 10 have higher success percentages (16.67% more) for mode-II as compared to mode-I. This is due to:

- In step 6 under mode-I, instead of pulling the thread laterally, the mentees pulled the suture thread upwards as soon as the mentors requested them. Whereas in mode-II, the mentors demonstrated the sub-step of lateral pulling using augmented tools and the mentees followed it. This shows that visual cues using augmented tools not only assist in better training of the mentees by following the mentors' actions, but also support the mentors by ensuring that they are able to effectively explain their instructions, without missing out any minor sub-steps.
- In step 10, similar behaviours were observed as in the above step 6.

In stage I (Fig. 4f), step 10 has a higher success percentage for mode-II (91.67%) than for mode-I (50%). This is due to:

- In step 10, the sub-steps of pulling the non-dominant hand first and of tightening in a lateral direction were forgotten by the mentees when performing the test under mode-I. This shows it is easier for the mentees to recall steps from visual memory supported by verbal explanations rather than just verbal instructions, as done in mode-I.

2) Stage I versus stage II: For both mode-I (Fig. 4g) and mode-II (Fig. 4h), the success percentages either remain the same or decrease for stage-II as compared to stage-I.

IV. Discussion

The study compares traditional in-person hands-on mentoring (mode-I) with remote tele-mentoring (mode-II). It was observed that teaching steps in mode-I took longer when the mentor had to assume control of the surgical instruments, since the mentees struggled to comprehend the steps through verbal instructions alone. On the other hand, mode-II facilitates continuous guidance through combined audio-visual cues. Mentees taught under mode-II performed better during the testing stage where they needed to recall breakdown of steps. Visual demonstration of steps using augmented surgical instruments assisted mentees to memorize the tasks. In addition, the mentor was able to give clear directions to the mentee with the use of augmented surgical instruments that resulted in effective communication.

There were some limitations in this study. First, each mentee has a different perception of the depth. It was difficult for some mentees to understand the relative positioning of the surgical instruments by visualizing the operative field on a two-dimensional screen. Due to this, certain steps (such as step 4 and step 8 that involve wrapping thread around one tool using the other) were performed at different paces by the mentees. Second, the current study does not take into consideration personal traits (like stress and frustration) of the mentees that may affect the performance. For example, two mentees due to frustration aggressively handled the tissue towards the end of the experiment. As the user interfaces play a major role in sending the instructions from the mentor to the mentee, further scenario specific end-user studies would be required to assess the learning curve [33]–[35].

The study identified several limitations specific to mode-II. Firstly, during stage-I, mentors occasionally provided ambiguous instructions, referring to surgical instruments using vague terms such as ”this” or ”that,” which posed challenges for mentees in understanding their intended actions. This highlights the importance of developing a structured surgical tele-mentoring curriculum with standardized terminology and protocols for mode-II [36]–[39]. Furthermore, the continuous rendering of augmented instruments resulted in visual hindrances by obstructing the view of the operative field. This was evident when the mentors forget to remove the augmented instruments from the scope field-of-view after demonstrating the surgical step. This requires adding automated transparency features for augmented tools when mentoring is not needed.

Although the study focused on the clinical paradigm of laparoscopic minimally invasive surgery (MIS), the concept of utilizing a gameplay environment could potentially be expanded to encompass endoluminal and transluminal robotic interventions as well [40]–[43]. This suggests that the benefits and applications of using a gameplay environment for surgical training and simulation may extend beyond laparoscopic procedures. The ability of the mentee to observe the mentor's point of view and precisely map the tool movement in real time aids in the remote transfer of surgical skills. Apart from tool motion, fusion of preoperative image data to the operative field in AR environment can generate guidance contours [44], [45] during the gameplay.

The study compares traditional in-person hands-on mentoring with remote tele-mentoring gameplay where the mentor and the mentee are physically located apart. Both the modes of mentoring displayed equivalent results when evaluated against the duration required and the success achieved for teaching the surgical skill of intracorporeal tissue suturing. Using augmented surgical instruments, the mentor can provide clear and detailed instructions to the mentee in real-time. These instructions are effectively conveyed through visual cues displayed near the operative field, allowing the mentee to recall and comprehend them thoroughly. The study findings

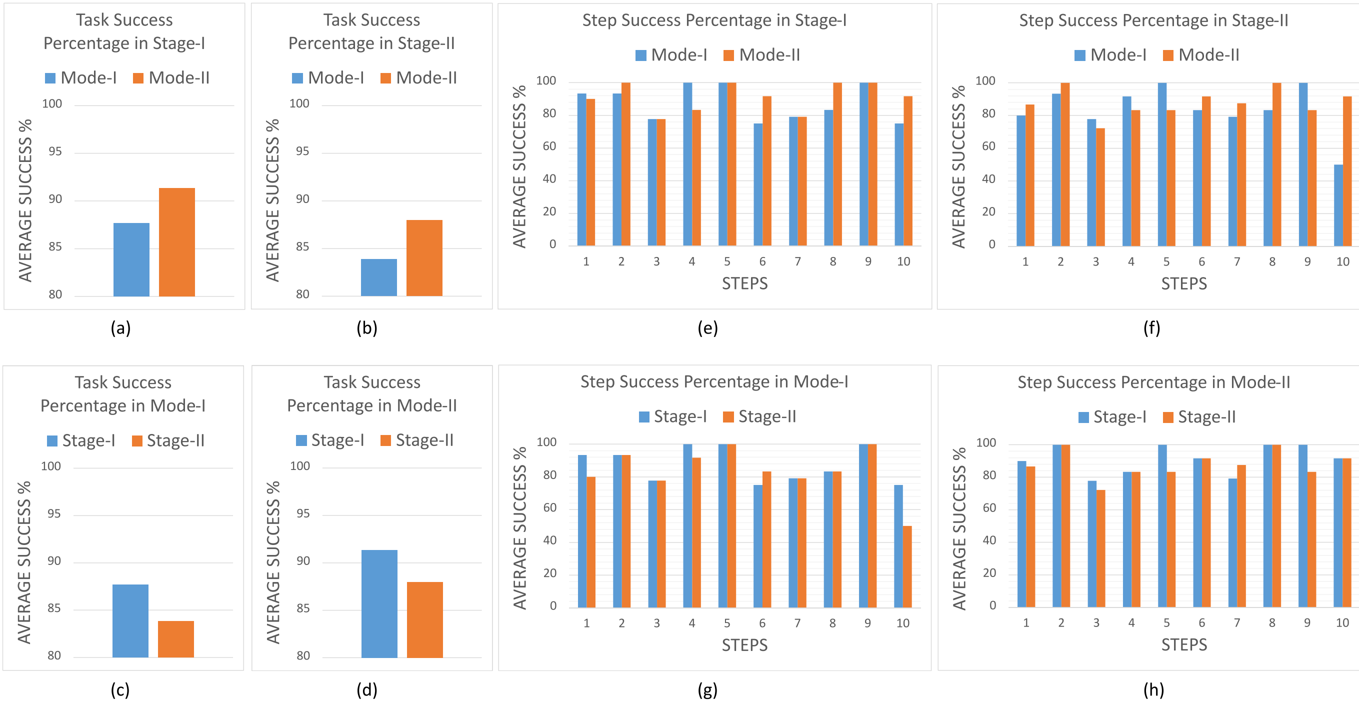

Fig. 4. (a) Surgical task success percentage in stage-I, (b) Surgical task success percentage in stage-II, (c) Surgical task success percentage in mode-I, (d) Surgical task success percentage in mode-II, (e) Surgical steps success percentage in stage-I, (f) Surgical steps success percentage in stage-II, (g) Surgical steps success percentage in mode-I, (h) Surgical steps success percentage in mode-II.

are expected to have a positive impact on surgical training using a gameplay by contemporizing the age-old "see one, do one, teach one" model using technological advances in VR/AR simulation and network protocols. It will enable centralization of multidisciplinary mentor-expertise for guiding the mentee, leading to a well-rounded surgical training curriculum.

V. Conclusion

Surgical training through remote tele-mentoring gameplay is comparable to the traditional approach to training, in teaching and learning of surgical skills. Mentors can provide perspicuous instructions in real-time, and mentees are able to thoroughly recall and demonstrate retention of acquired skills. This can further assist mentee to strengthen their surgical skills, adding to their overall professional development. It can be adapted to meet a variety of surgical simulation training needs. Thus, the remote tele-mentoring gameplay mode can facilitate surgical skill transfer and may be used as an alternative when access to expert in-person surgical training is unavailable.

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